Re-examining classical climate models: A state of the art radiative-convective model

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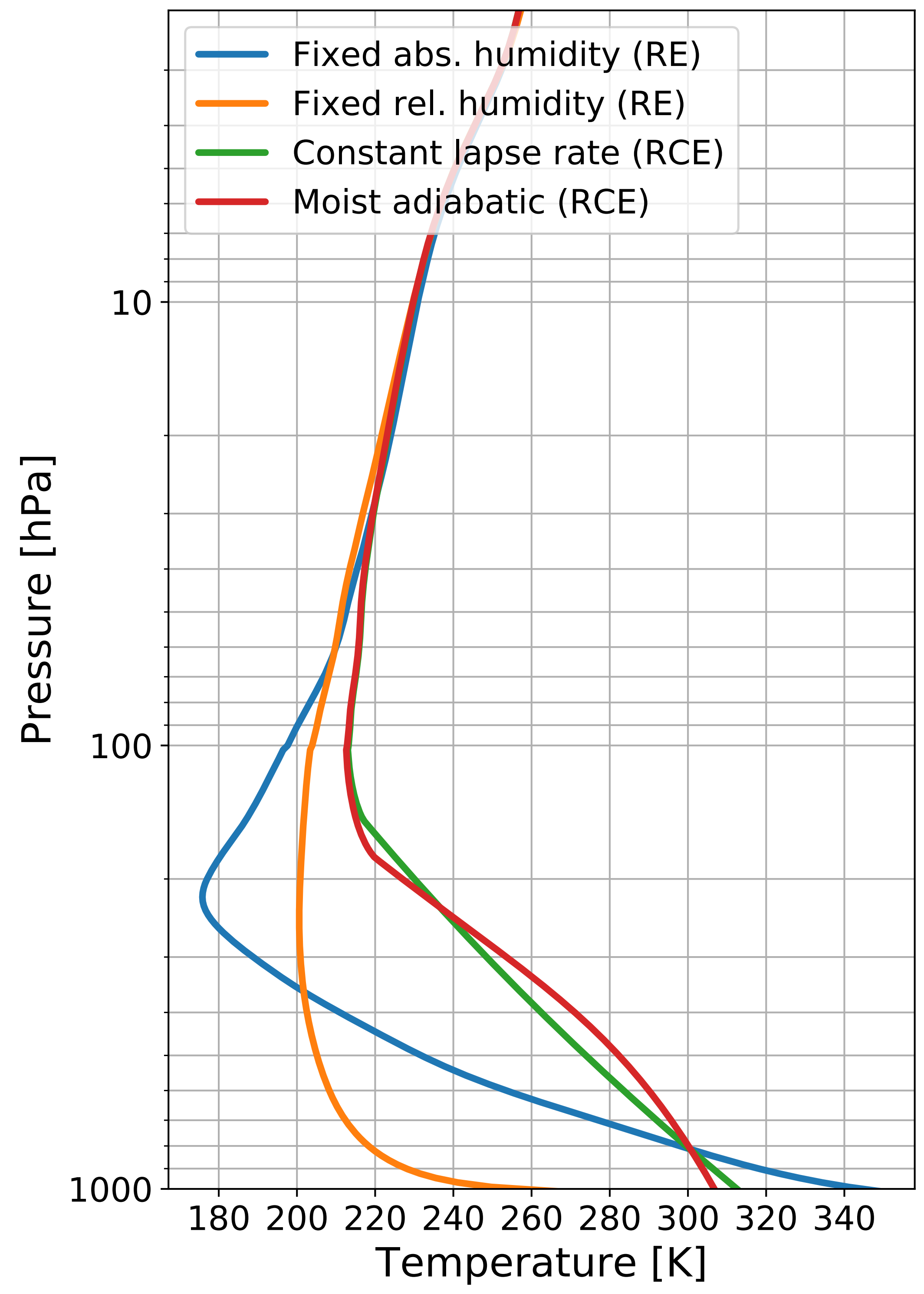
Back to the roots

Following the pioneering work by Manabe and Wetherald (1967) radiative-convective equilibrium models (RCE) have been used to investigate Earth's climate for more than 50 years now. Despite the number of preceding studies and the relative simplicity of 1D RCE, results in literature show a large spread.

We construct a flexible framework to perform RCE simulations to a broad variety of experiments using state of the art knowledge of radiative transfer. We want to systematically benchmark the impact of different assumptions on climate sensitivity and vertical structure of our model to understand what causes the differences in the preceding studies.
An advantage to full GCMs is that we are able to run our model to numerical convergence.

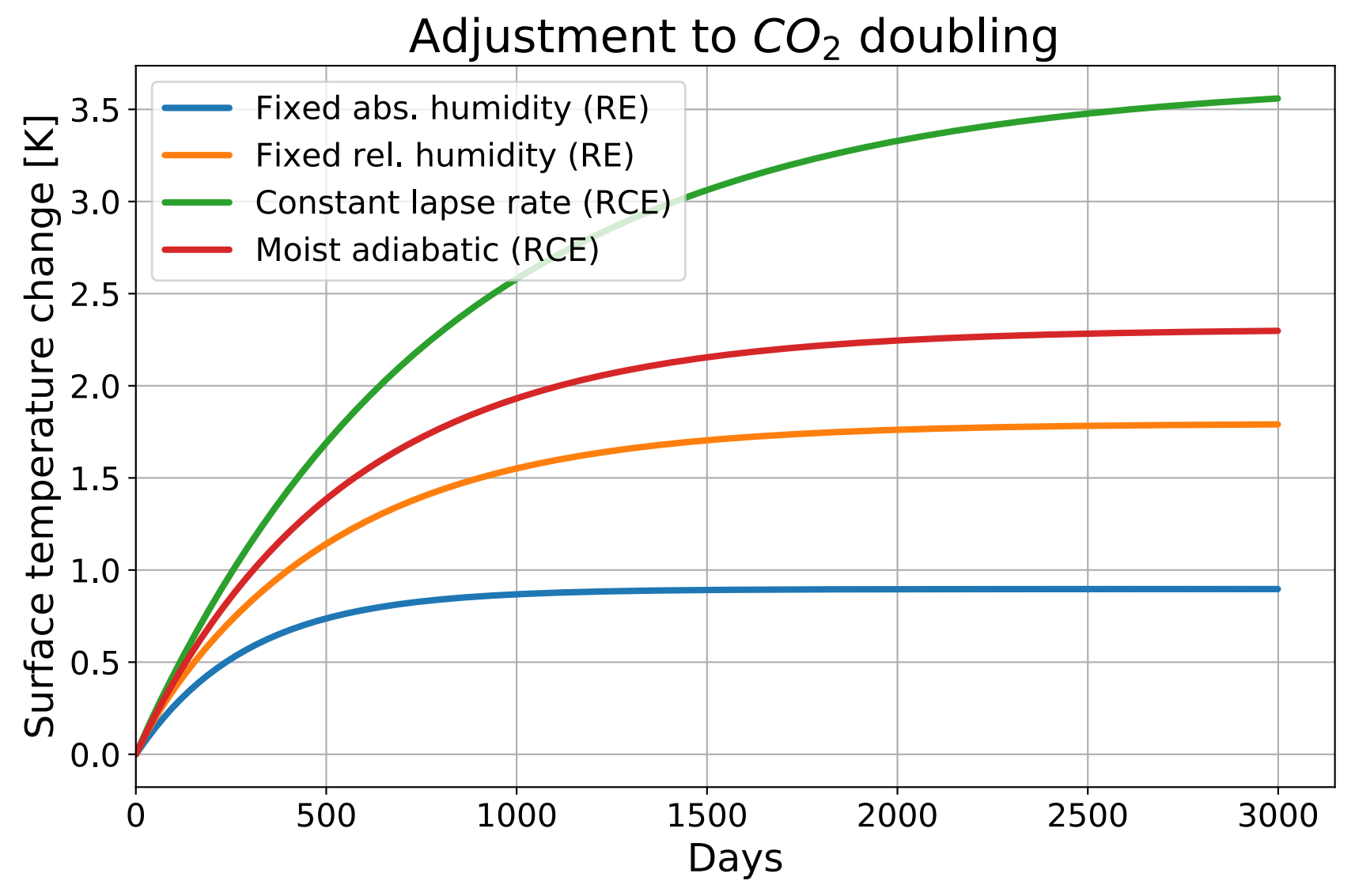


Model set-up

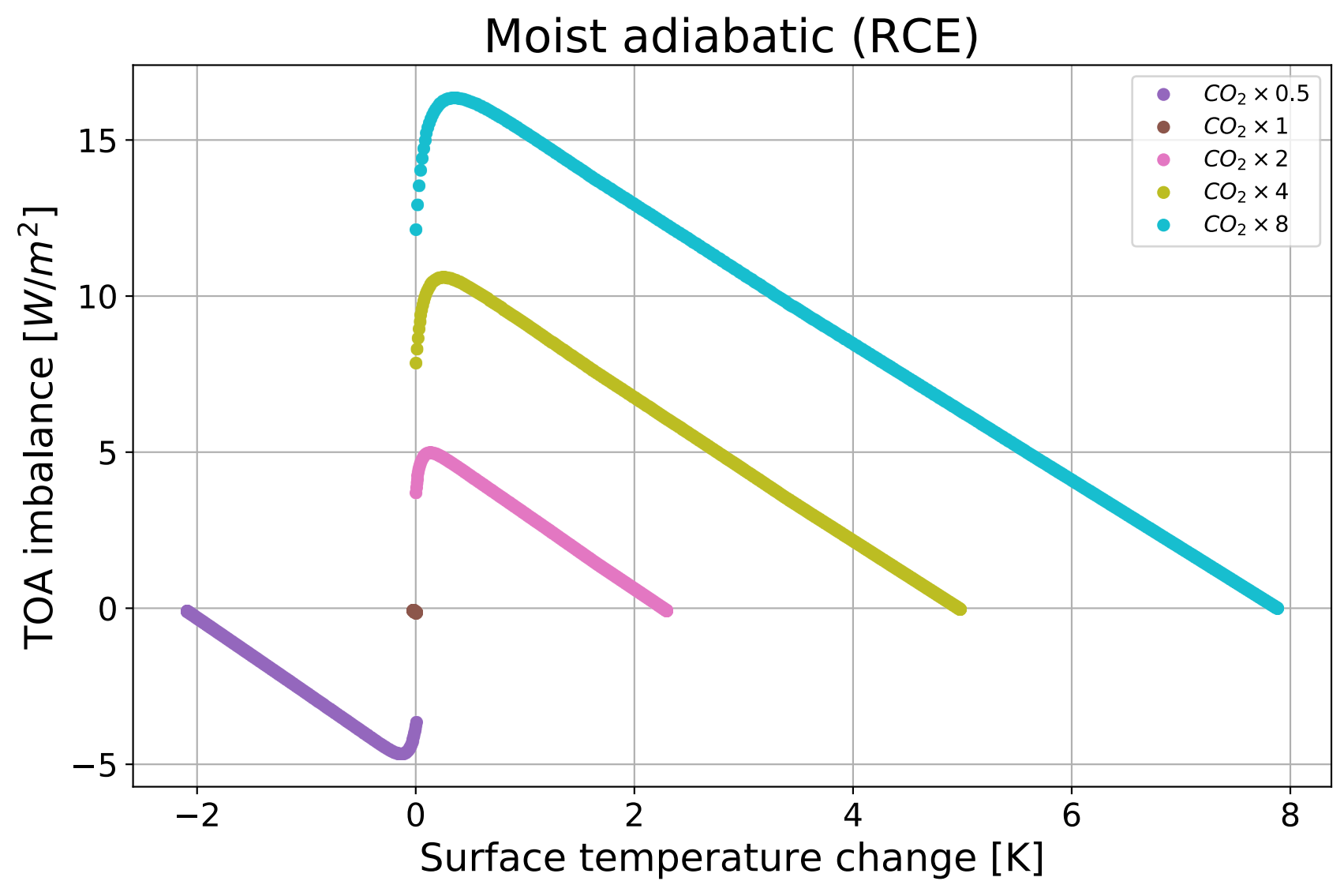
- Builds on the PSrad radiation scheme used in the latest version of the MPI-ESM.
- Runs under clear-sky conditions.
- Different handling of atmosphere physics is possible e.g. preserving the absolute or relative humidity.
- A convective adjustment can be applied to the troposphere (constant or moist-adiabatic lapse rate).
- The RCE presented in the results were run with fixed relative humidity.
- 200 pressure levels were used (0.25 K difference in surface temperature compared to a reference run with 1000 levels)
- We plan to include clouds to test different hypotheses (e.g. PHAT, FAT).

Climate sensitivity

The equilibrium surface temperatures for CO_2 doubling are highly sensitive to the chosen atmosphere physics (0.89–3.56 K). The temperature change for a constant lapse rate (3.56 K) is 1.26 K larger than that for the moist adiabatic lapse rate (2.3 K), in agreement with Hummel and Kuhn (1981).



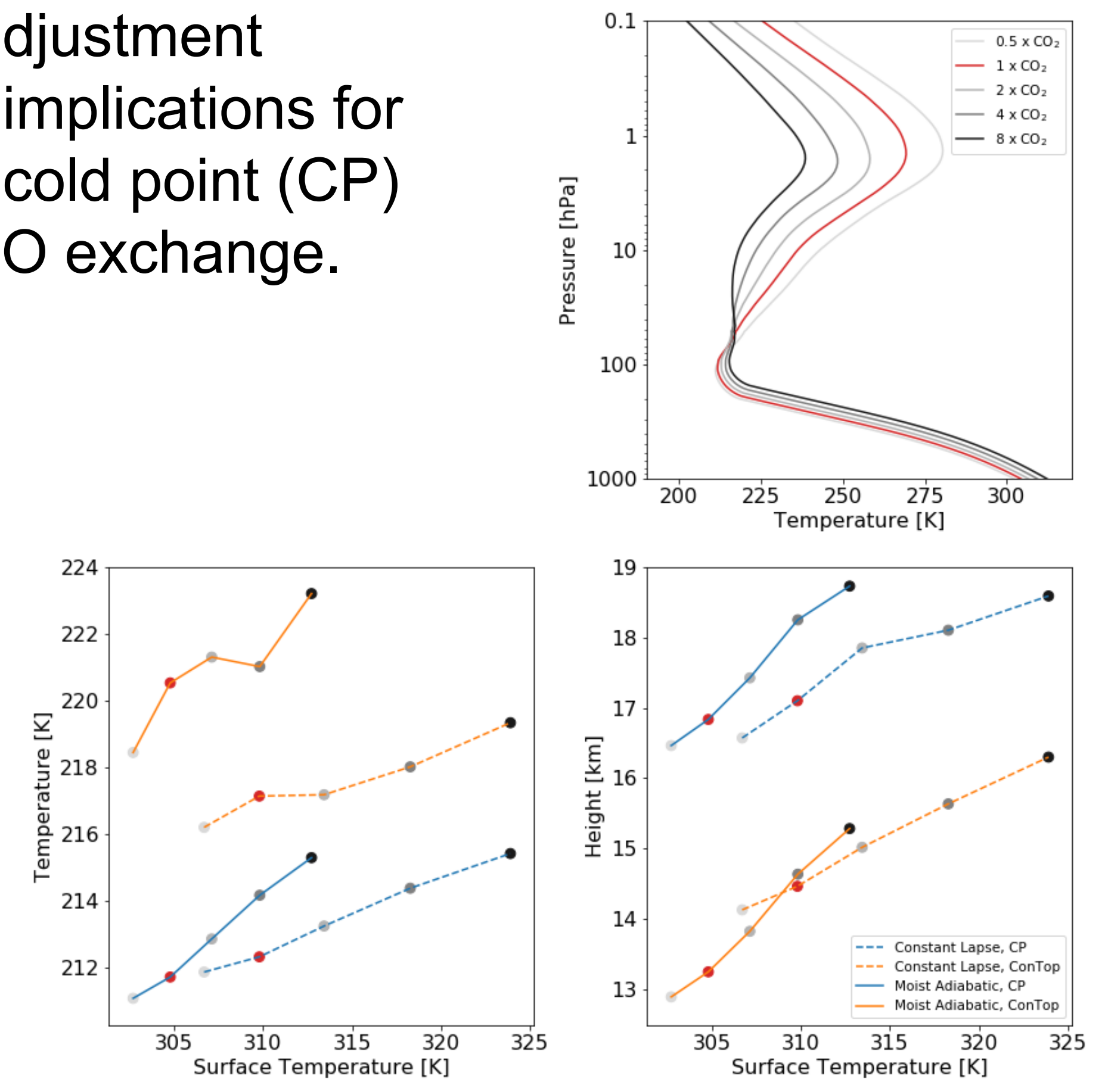
The climate sensitivity is robust for a wide range of CO_2 concentrations. Results for decreased CO_2 show the same sensitivity. For all runs, an increase in the initial forcing, due to stratospheric adjustment, can be seen before the well known slope.



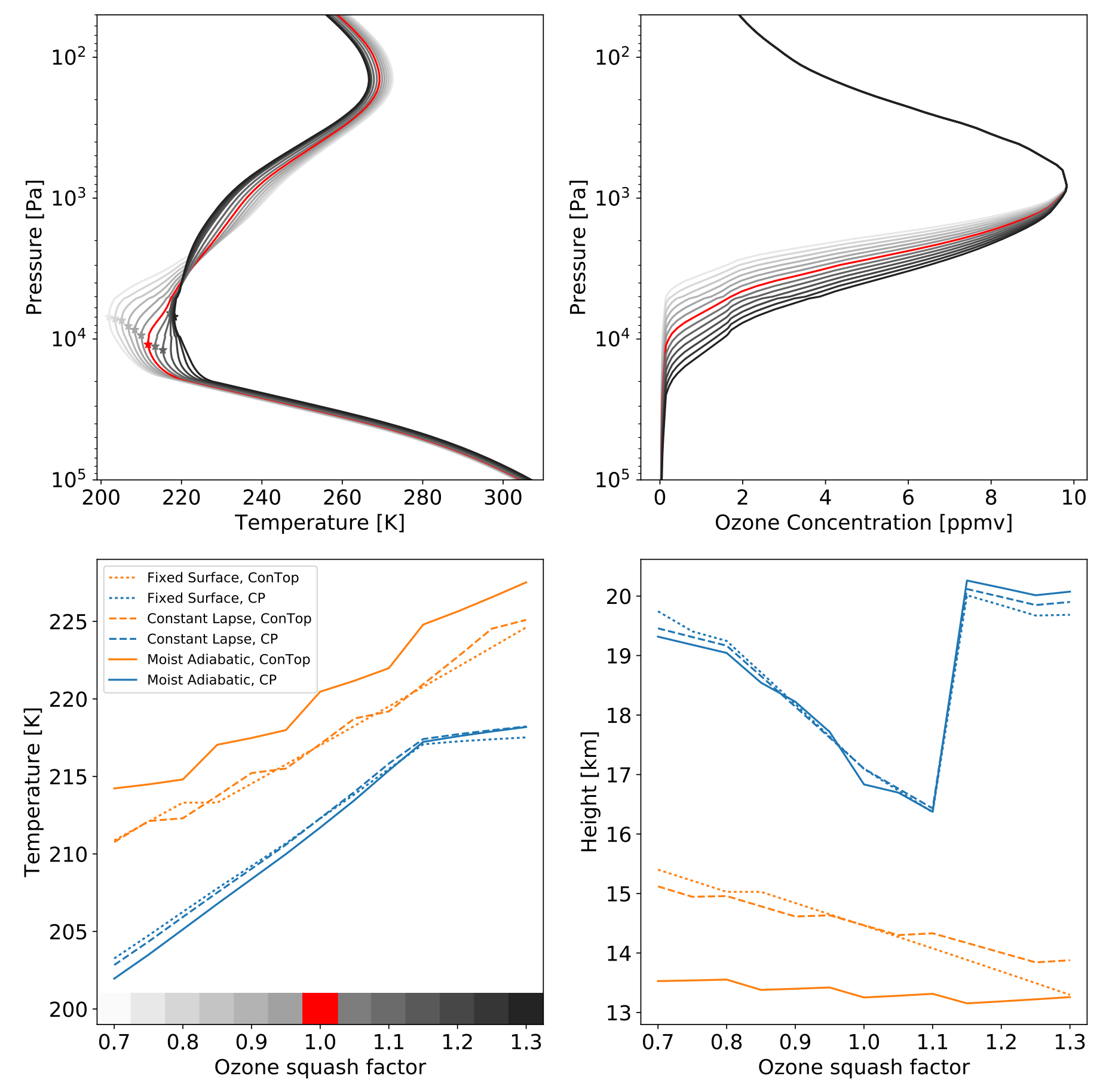
Vertical structure and tropopause

The top level of our convective adjustment (ConTop) is of interest due to its implications for cloud formation height, as is the cold point (CP) for tropospheric-stratospheric H_2O exchange.

With increasing CO_2, both the ConTop and CP increase in temperature and height. Runs were also performed with a fixed surface temperature, producing small responses to CO_2 changes (in agreement with Thuburn and Craig 2002), implying that the ConTop and CP changes are a response to surface and tropospheric warming rather than the CO_2 concentration itself.



We also investigate the effect of changing the ozone profile, following Birner and Charlesworth (2017). An upward shifted ozone profile (squash factor < 1) gives rise to colder ConTop and CP temperatures. In addition to previous studies, we find that this is also the case for a set-up with variable surface temperature.



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